APPENDIX C

CRITERIA FOR DETERMINING SPH AND PMH WIND FIELDS

C-1. General. This appendix summarizes the necessary meteorological criteria presented in Technical Report NWS 23 (item 57 in Appendix A) for developing wind fields in connection with a Standard Project Hurricane (SPH) and the Probable Maximum Hurricane (PMH). Details and justification for adopting the various criterions as presented herein are omitted; however, such information can be found in the original report.

C-2. Meteorological Parameters.

a. The various meteorological parameters used for describing hurricane wind fields are identified as:

peripheral pressure (p_n)
central pressure (p_o)
radius of maximum winds (R)
forward speed (V_f)
track direction (θ)
inflow angle (α)

which were presented in Chapter 1. In defining wind fields it is also necessary to consider wind speed distribution and the limits of rotation of the wind.

b. All of the parameters, with the exception of the peripheral pressure p_n and the inflow angle α, generally vary along the Gulf and East Coasts of the United States. As a consequence the National Weather Service developed a standard chart with distances along the abscissa with mileposts beginning (mile 0) at the United States-Mexico border and ending at United States-Canada border. These mileposts are adopted for all storm surge studies conducted by the Corps of Engineers.

c. The meteorological parameters are to be determined as follows:

(1) Peripheral Pressure. For the SPH and PMH the peripheral pressure p_n or the sea-level pressure at the outskirts of the hurricane is to be taken as 29.77 in. (100.8 kPa) and 30.12 in. (102.0 kPa), respectively. (It is noted that atmospheric pressure given herein in units of inches (in.) implies inches of mercury.)

(2) Central Pressure. The lowest sea-level pressure p_o at the hurricane center is determined from Figures C-1 and C-2 for the SPH and PMH for a given coastal location.

(3) Radius of Maximum Winds. Figures C-3 and C-4, respectively, show the radial distances from the hurricane center to the regions of maximum winds R for SPH and PMH. It is to be noted that R can vary in a range between the upper and lower limits specified.

(4) Forward Speed. The range of translation speed V_f of the hurricane center for the SPH and PMH is shown in Figures C-5 and C-6.

(5) Track Direction. The permissible range of track direction θ for the SPH and PMH is shown in Figures C-7 and C-8, respectively. Categories A, B, and C indicated in these figures refer to forward speed V_f of the hurricanes. These speed categories are defined in Table C-1.

C-3. Pressure Distribution. The mathematical expression for defining the pressure distribution (item 45 of Appendix A) within a SPH and a PMH is:

$$\frac{p - p_o}{p_n - p_o} = e^{R/r} \qquad [C-1]$$

in which p is the sea-level pressure at the radial distance r from the hurricane center. This expression is used to develop the maxi-

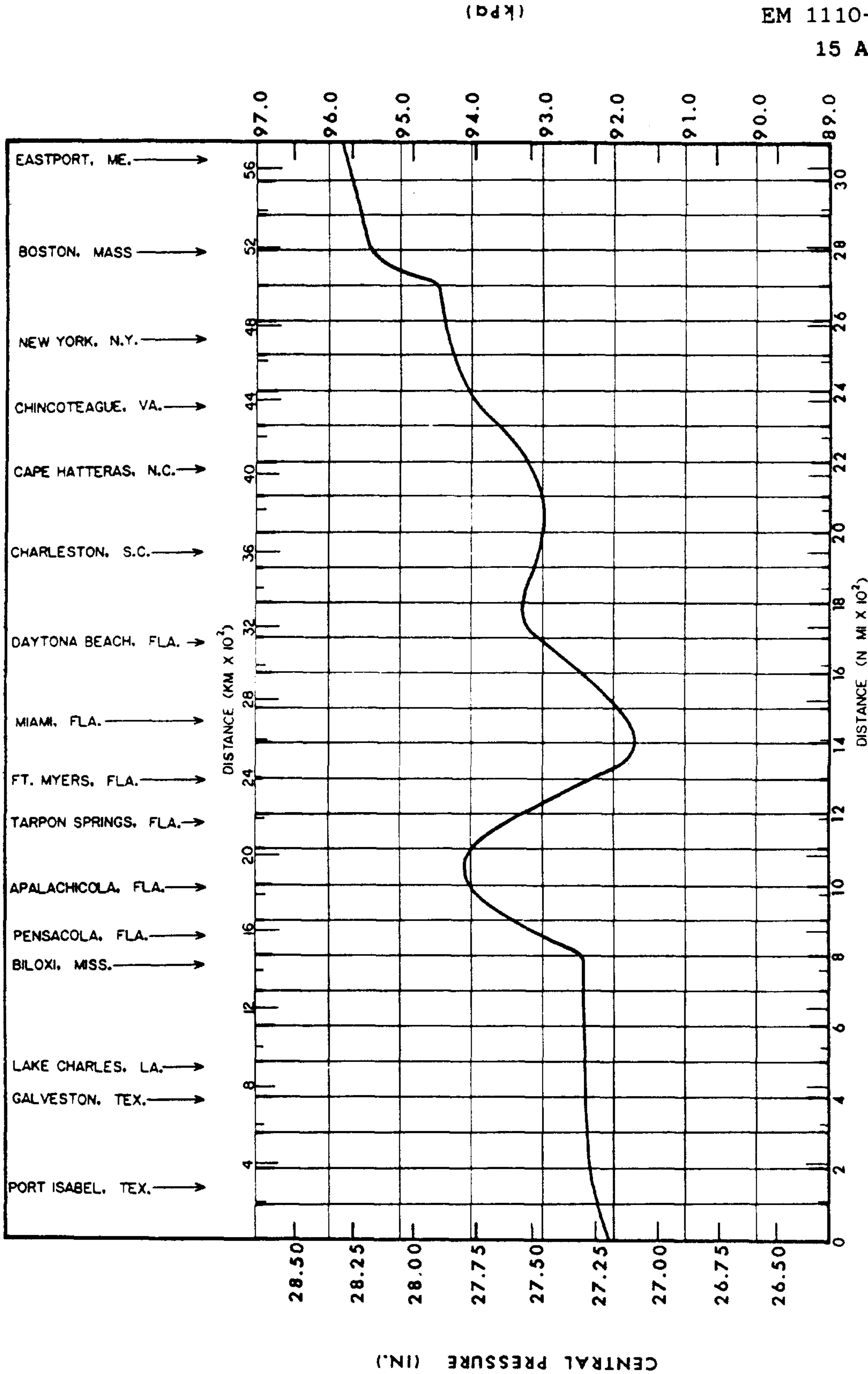

Figure C-1. Plot showing the SPH p_o. (item 57 of Appendix A)

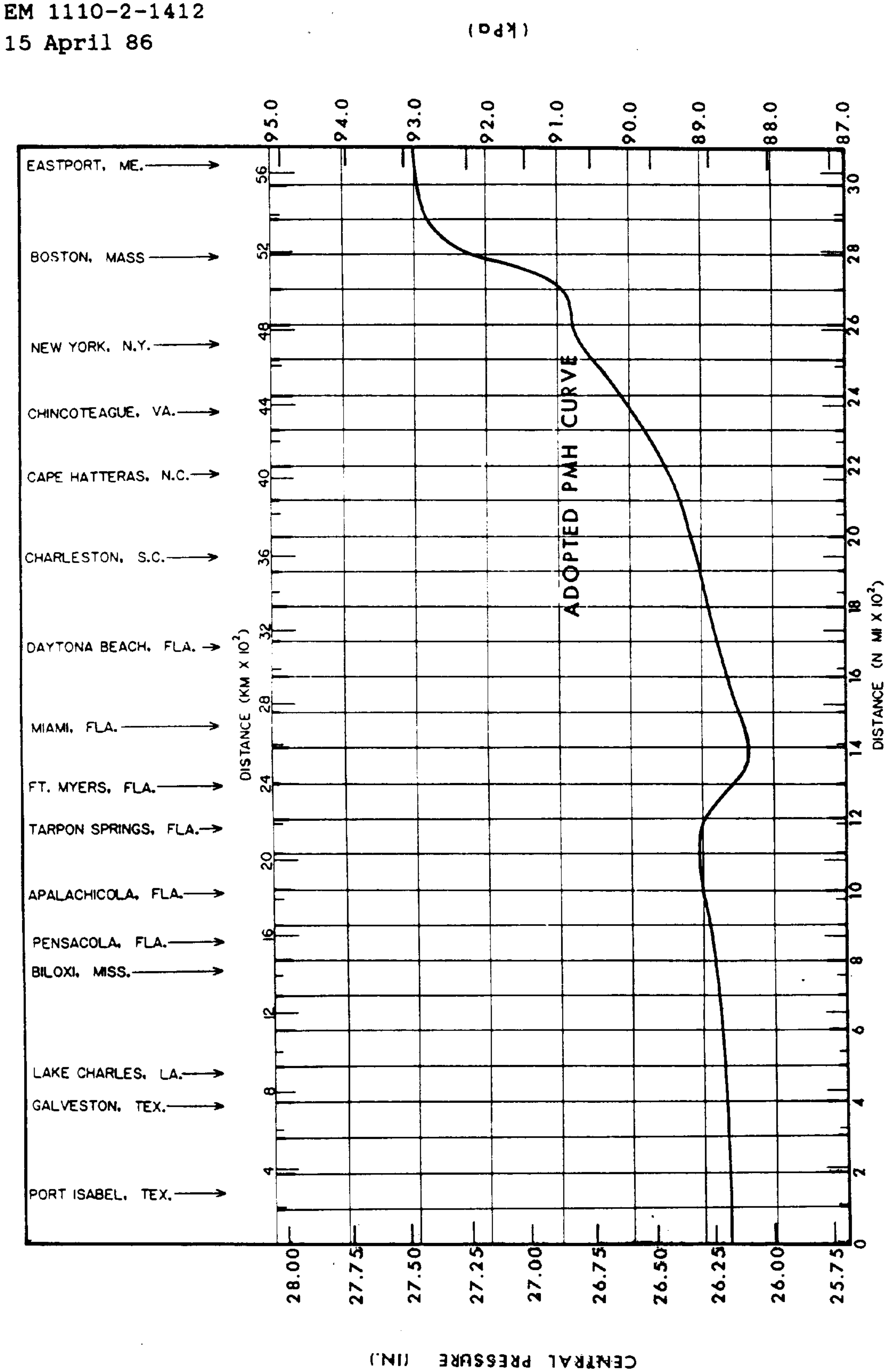

Figure C-2. Plot showing the PMP P_o. (item 57 of Appendix A)

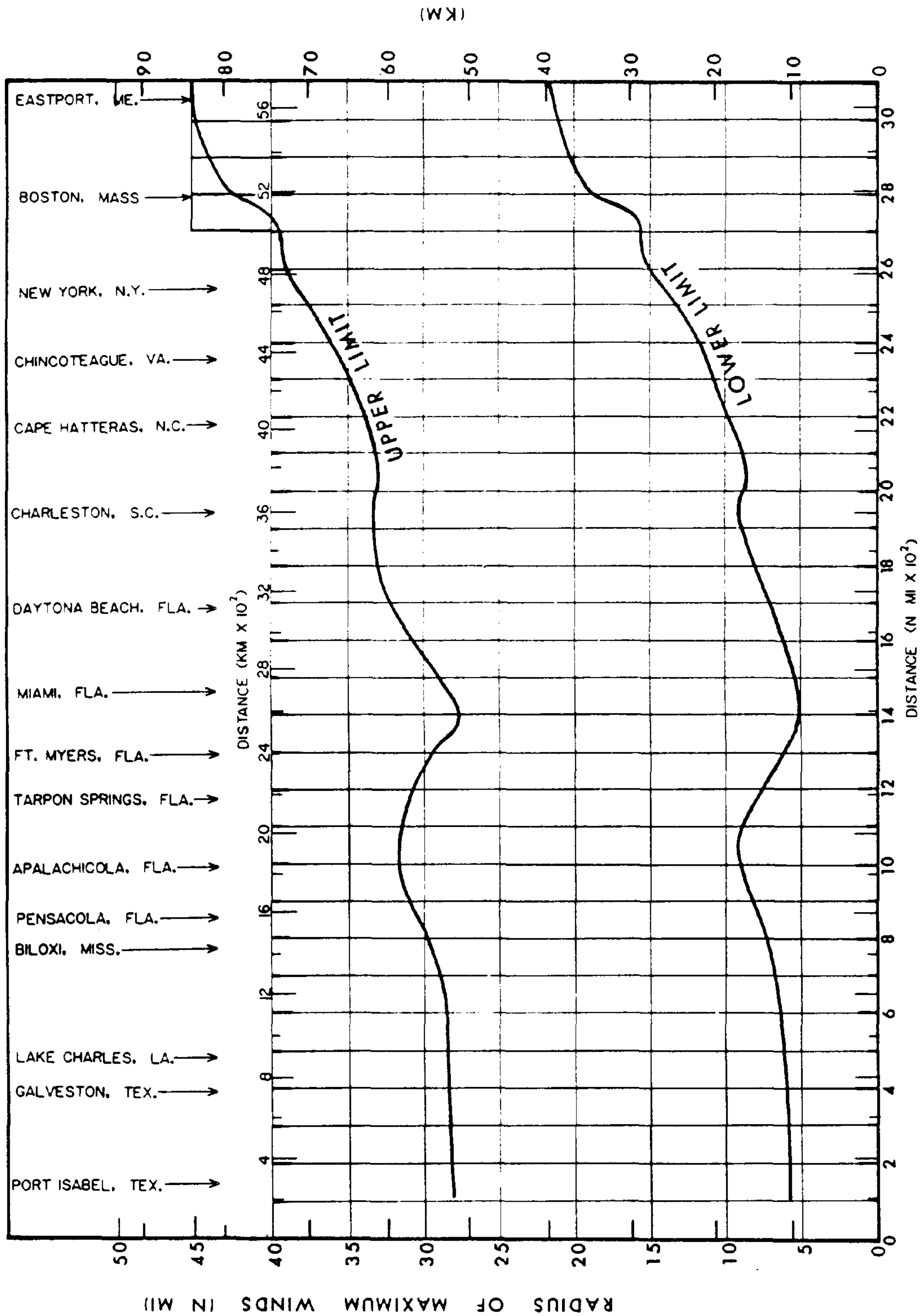

Figure C-3. Upper and lower limits of radius to maximum winds for the SPH. (item 57 of Appendix A)

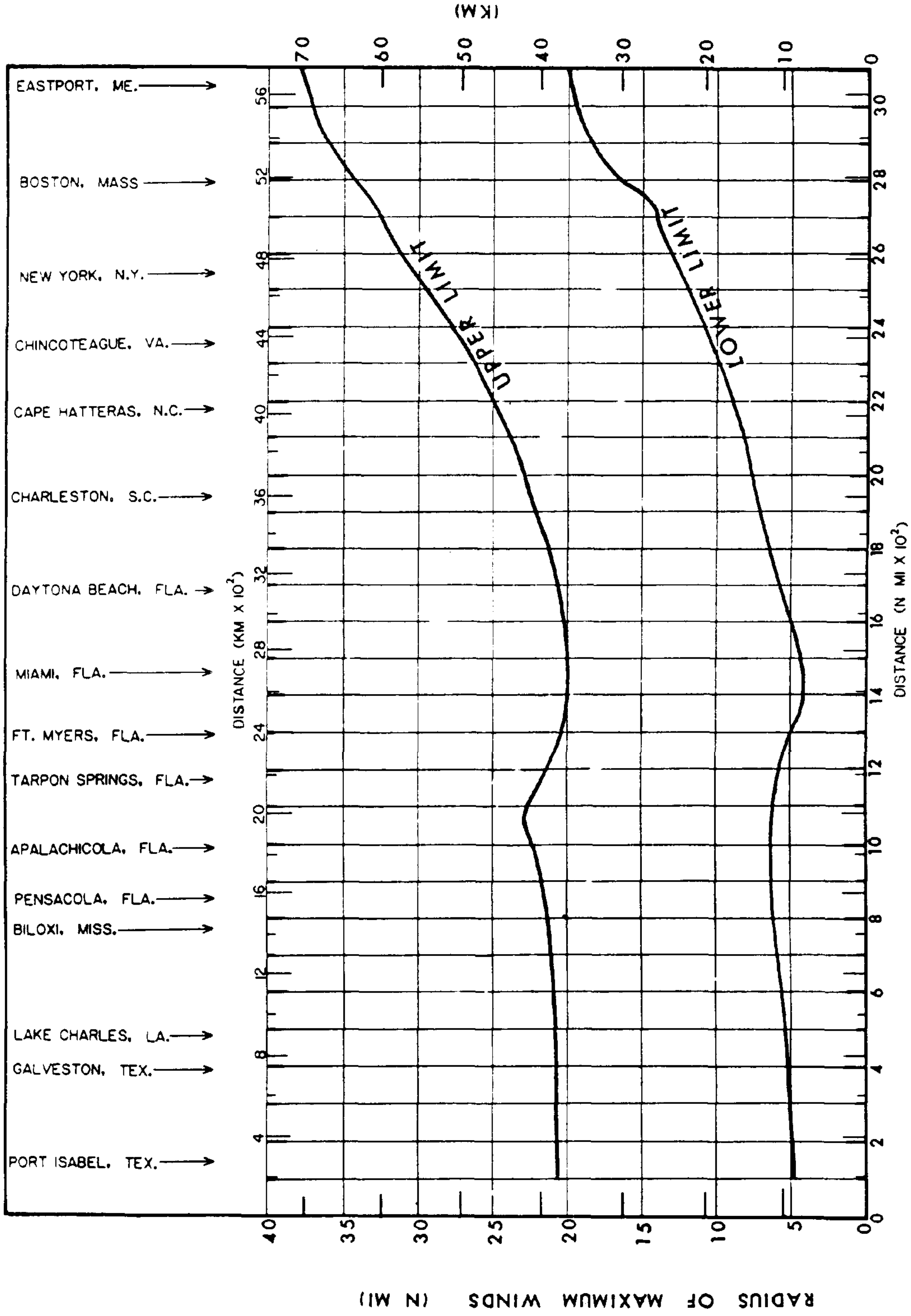

Figure C-4. Upper and lower limits of radius to maximum winds for the PMH. (item 57 of Appendix A)

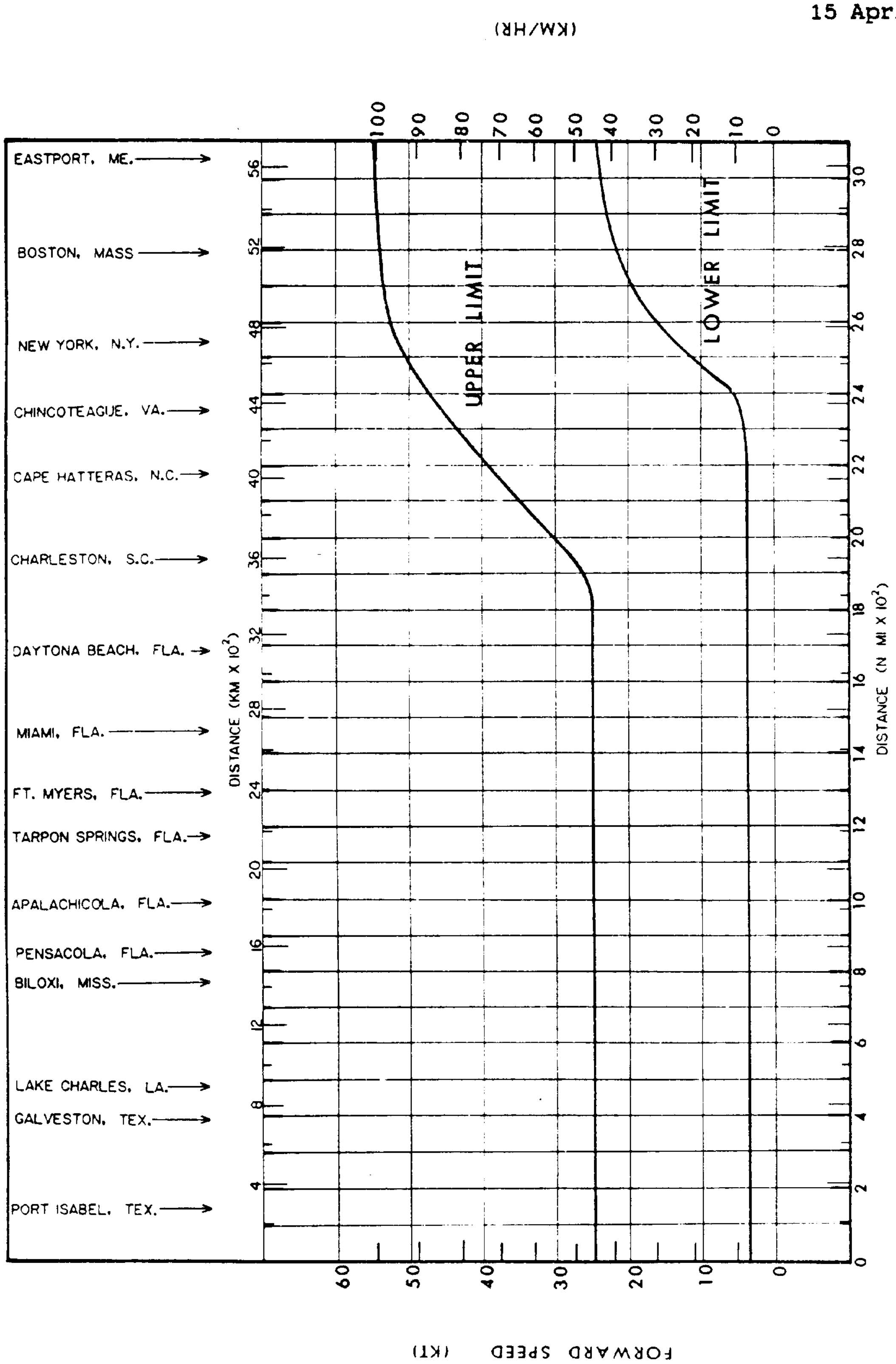

Figure C-5. SPH upper and lower limits of V_f. (item 57 of Appendix A)

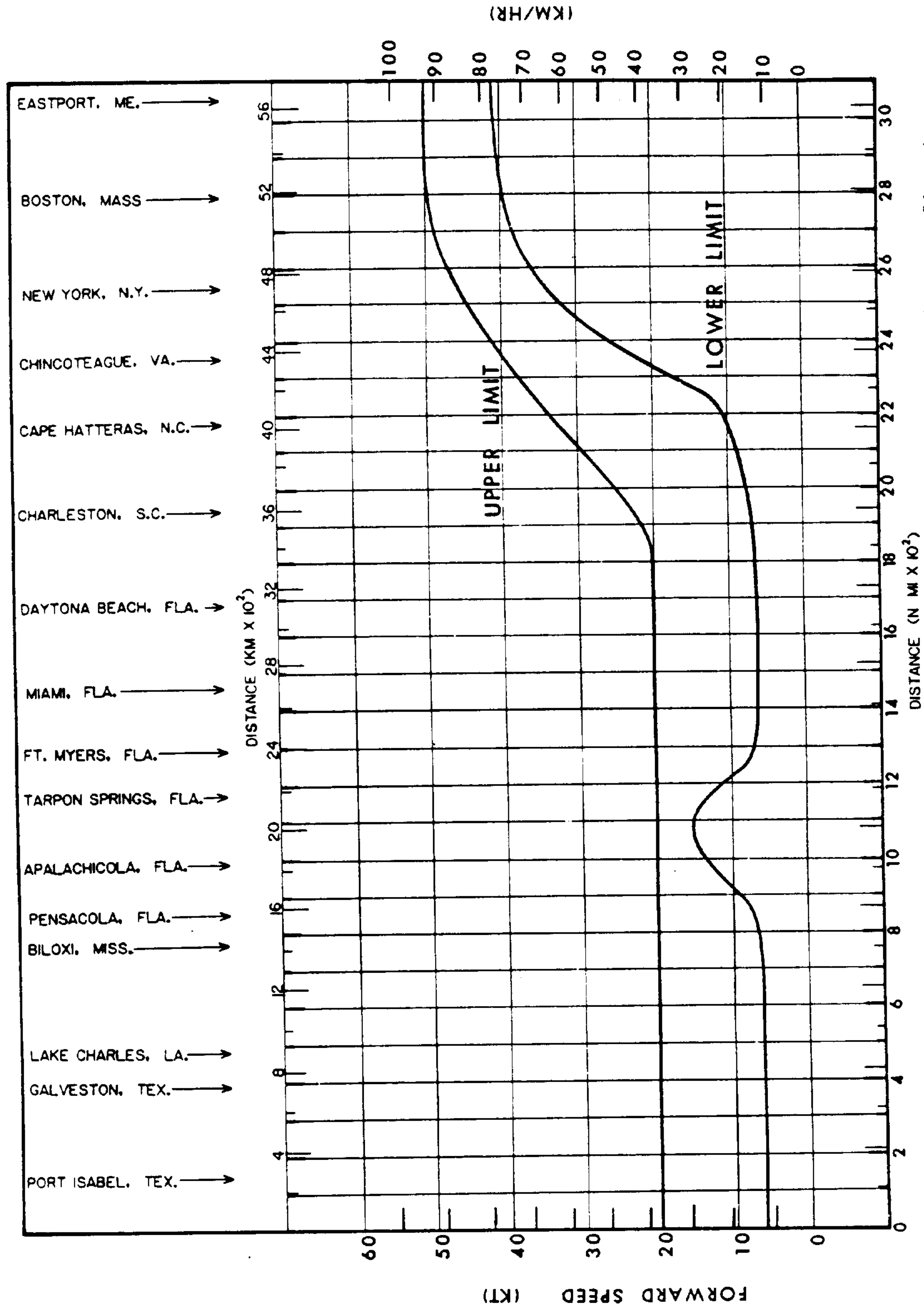

Figure C-6. PMH upper and lower limits of V_f. (item 57 of Appendix A)

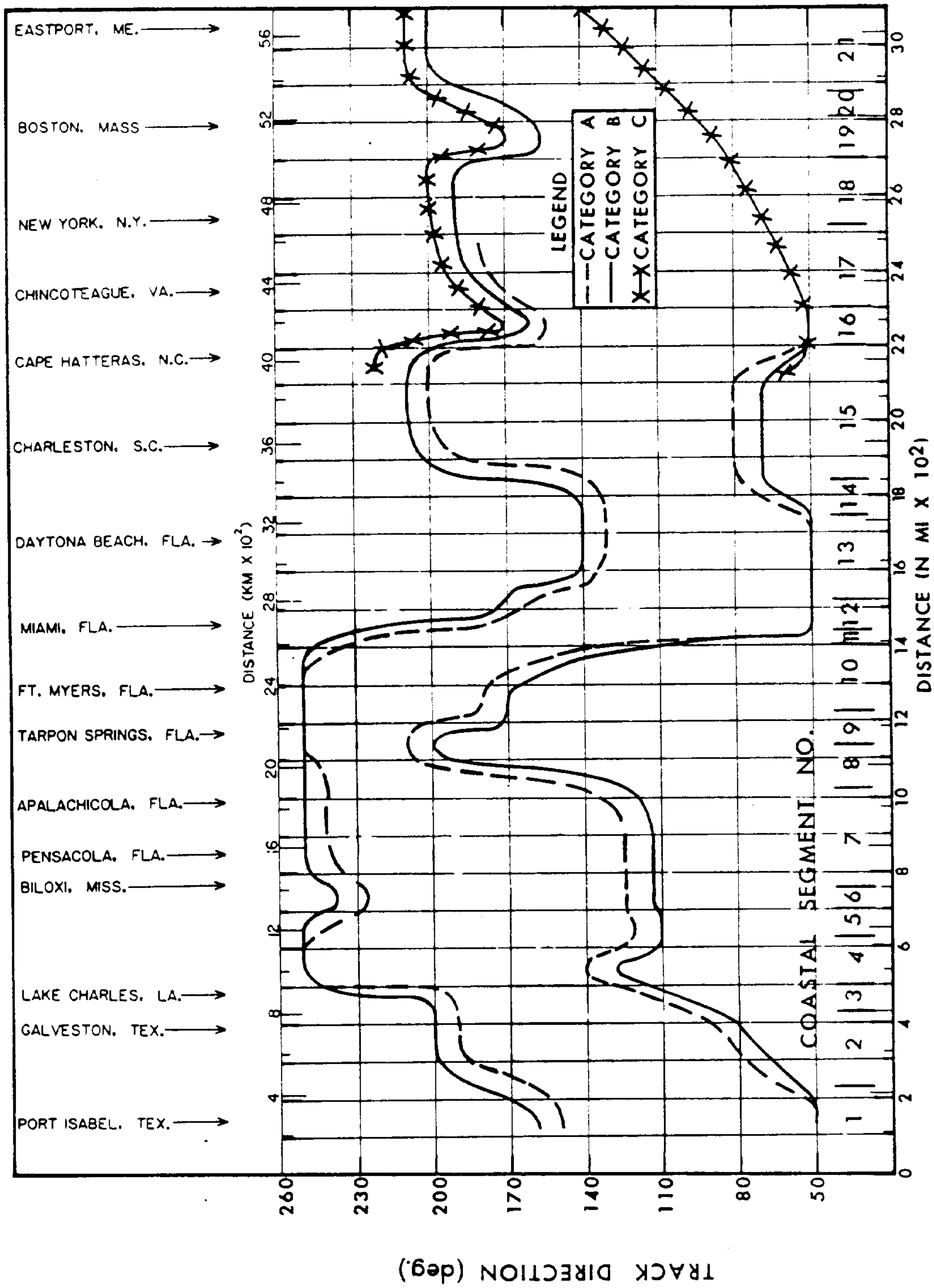

Figure C-7. Maximum allowable range of SPH θ. (item 57 of Appendix A)

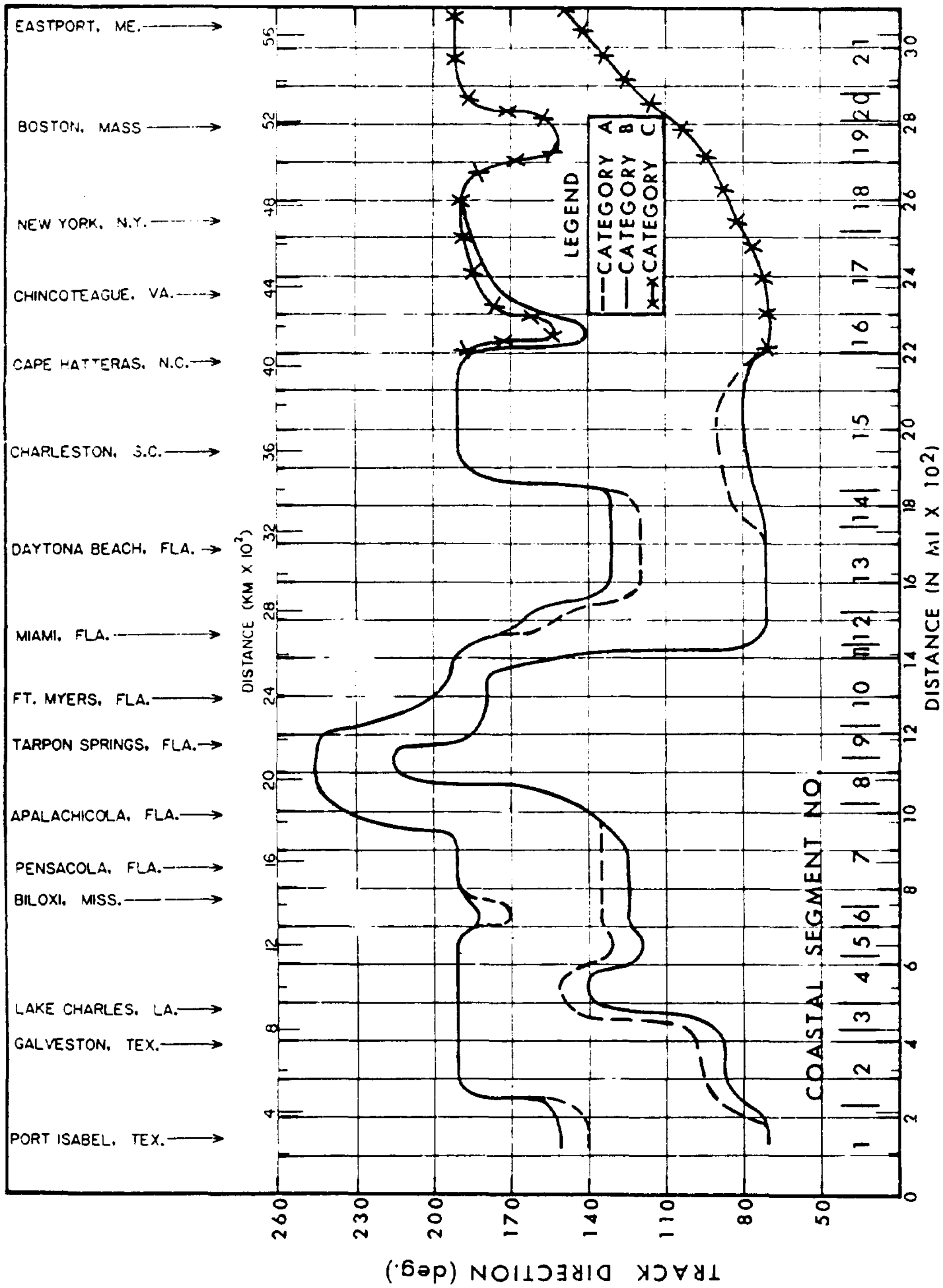

Figure C-8. Maximum allowable range of PMH θ. (item 57 of Appendix A)

Table C-1

Speed Categories Used in Determining
the Relation Between V_f and θ.

Speed Category		Forward Speed
SPH	A	6kt $\leq V_f \leq$ 10 kt
	B	10 kt $\leq V_f \leq$ 36 kt
	C	$V_f \leq$ 36 kt
PMH	A	4 kt $\leq V_f \leq$ 10 kt
	B	10 kt F $V_f \leq$ 36 kt
	C	$V_f >$ 36 kt

mum gradient wind speed as given in the subsequent section. In addition, this expression is used to develop a relation for evaluating the pressure setup which is covered in Appendix D.

C-4. Wind Field Specification. This section is concerned with estimating the winds 10m (32.8 ft.) above the water surface and the modification of wind when the rotating wind crosses overland areas.

a. Overwater Maximum Gradient Winds. The maximum gradient winds (V_{gx}) are the peak hurricane winds blowing parallel to the isobars under conditions of circular motion. An expression for this wind (see Chapter 12, NWS 23 (item 57 of Appendix A) for derivation) is

$$V_{gx} = K\,(p_n - p_o)^{1/2} - \frac{Rf}{2} \qquad [C-2]$$

in which f is the Coriolis parameter and K is a coefficient that is inversely proportional to the square root of the air density just above the water surface. Because air density is influenced by seasurface temperatures K is dependent on the earth's latitude. Figures C-9 and C-10 show the relation between the coefficient K and latitude for three units of measurement for the SPH and PMH, respectively.

b. Overwater Maximum Winds in a Stationary Hurricane. The maximum 10-m, 10-minute averaged winds for a hurricane at rest (V_{xs}) have been found from observations to be a fixed fraction of the maximum gradient winds V_{gx}. The adopted empirical relations for defining the maximum wind is

$$V_{xs} = 0.9 \ V_{gx} \text{ , for SPH} \qquad [C-3]$$

and

$$V_{xs} = 0.95 \ V_{gx} \text{ , for PMH .} \qquad [C-4]$$

c. Overwater Maximum Winds in a Moving Hurricane.

(1) An asymmetry factor must be added to the maximum winds in a stationary hurricane to account for a moving hurricane For a moving hurricane, the maximum wind V_x, for the SPH is:

$$V_{xm} = 0.9 \ V_{gx} + 1.5 \ (V_f^{0.63}) \ (V_{fo}^{0.37}) \cos \beta \qquad [C-5]$$

and for the PMH

$$V_{xm} = 0.95 \ V_{gx} + 1.5 \ (V_f^{0.63}) \ (V_{fo}^{0.37}) \cos \beta \qquad [C-6]$$

in which V_{fo} = 1 when units are in knots, 0.514791 when units are meters per second, 1.853248 when units in kilometers per hour, and 1.51556 when units are in miles per hour. The angle β is the angle between the hurricane track and the maximum surface wind vector. At a particular position in the right rear quadrant of a hurricane the maximum wind can blow in a direction parallel to the track direction, and in this case β =0 and cos β =1. However, the region of maximum winds are allowed to occur at any position between 0 degrees and 180 degrees clockwise from the track direction. The latter limits of rotation of the wind fields were adopted based on observations from past hurricanes.

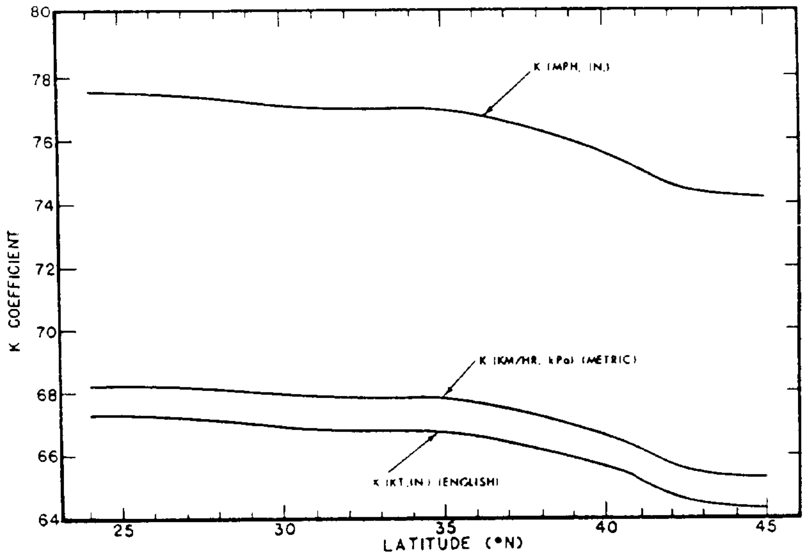

Figure C-9. Values of the latitude - dependent K coefficient for three units of measurement for the SPH. (item 57 of Appendix A)

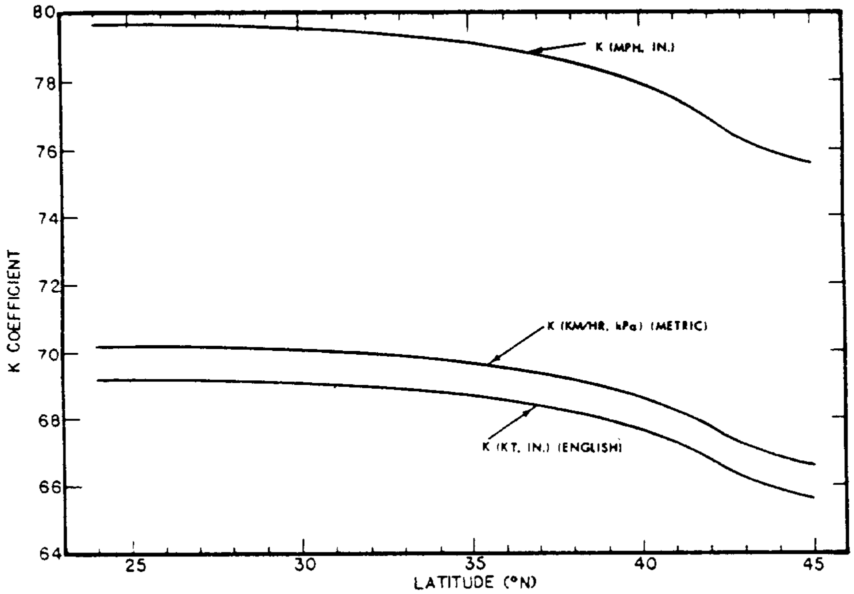

Figure C-10. Values of the latitude - dependent K coefficient for three units of measurement for the PMH. (item 57 of Appendix A)

(2) In previous discussions, the wind relations given provide estimates of the maximum winds. A general expression for estimating the wind speed V_r at any radial distance r from the hurricane center is:

$$V_r = V_s + 1.5\ (V_f^{0.63})\ (V_{fo}^{0.37}) \cos \beta \qquad [C-7]$$

in which V_s is the wind speed in stationary hurricane at radius r. Figure C-11 shows the relative wind speed ratio V_s/V_{xs} versus the distance r outward from R for various radii R. Figure C-12, on the other hand shows the speed within the radius of maximum winds.

d. Wind Inflow Angle. As indicated in Chapter 1, winds blow spirally inward toward the hurricane center. The angle between a tangent line on an isovel circle and the associated wind vector is defined as the wind inflow angle α. The inflow angle in degrees versus the distance from the hurricane center is shown in Figures [C-13] and [C-14] for the SPH and PMH, respectively, for various radii R.

e. Wind Modification Due to Frictional Effects. When revolving hurricane winds begin to sweep over inundated coastal terrain the winds lose speed due to increased surface friction. At the coast there is an abrupt decrease in wind speed and as the wind continues to blow overland the wind speed is further reduced until finally an approximate state of equilibrium is reached where no further reduction occurs. After the wind circles back over the ocean, or encounters a water body such as an embayment, the wind speed begins to increase and if the wind travels over the water surface for a sufficient distance it is essentially restored to its full strength. In general, the reduction of wind speed in inundated low-lying land areas due to frictional effects can be determined from

$$V_k = k\ V_r \qquad [C-8]$$

where V_k is the wind speed adjusted for frictional resistance and k is the surface friction coefficient. Figure C-15 shows the variation of k with distance along the wind path for four different

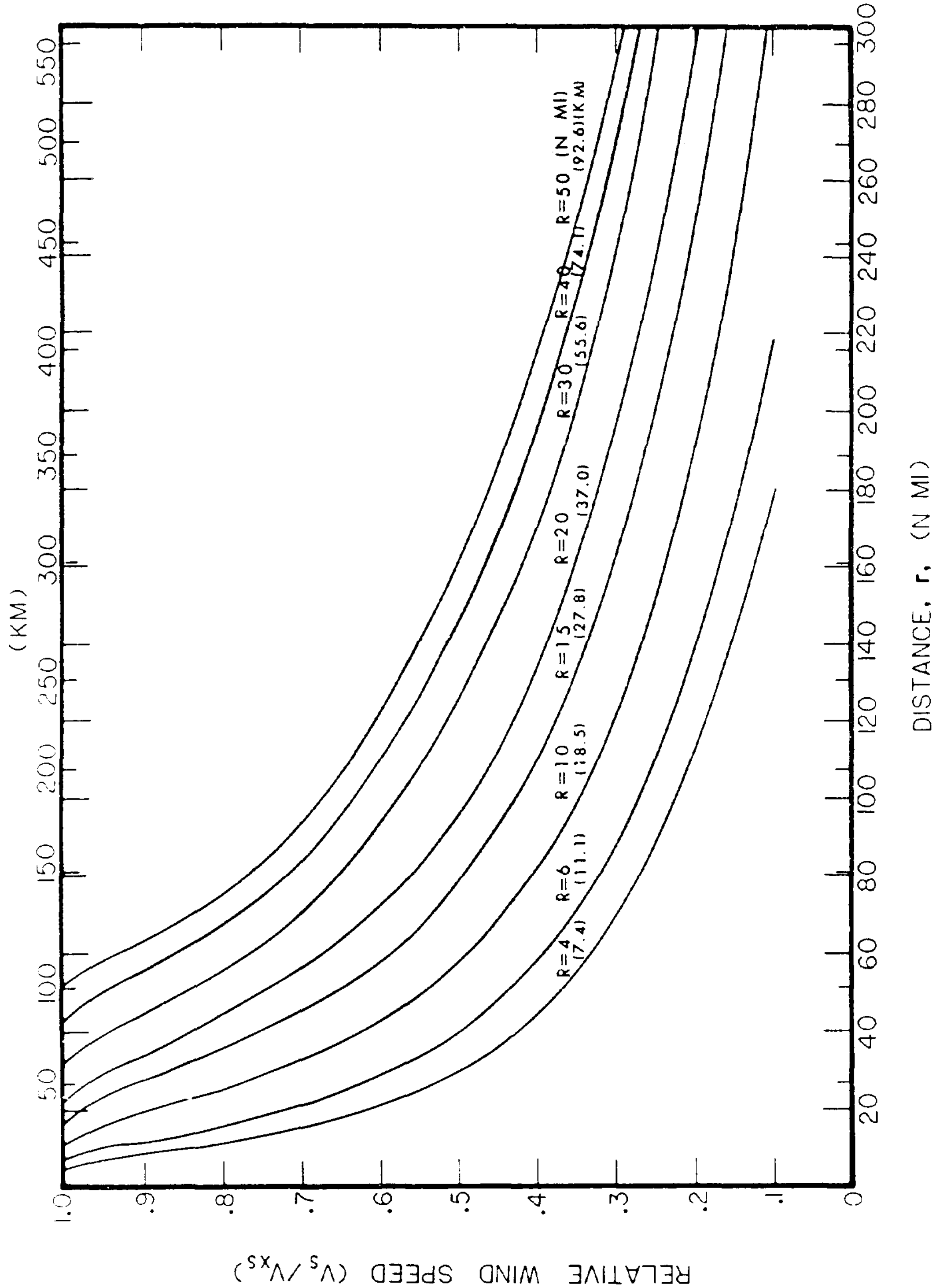

Figure C-11. Standardized wind profiles outward from R for the stationary SPH and PMH. (item 57 of Appendix A)

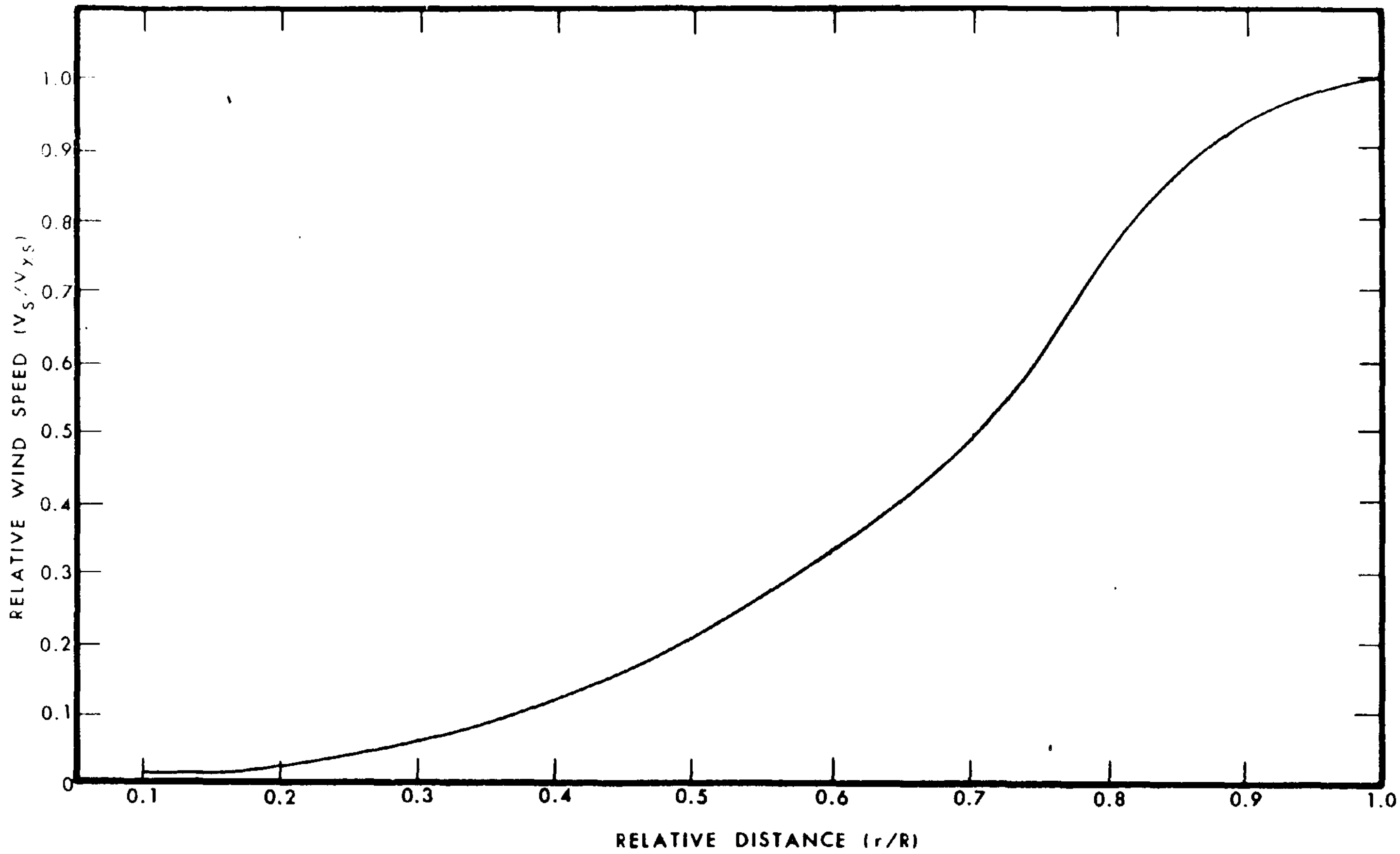

Figure C-12. Variation of relative wind speed with relative distance within the radius of maximum winds for the stationary SPH and PMH. (item 57 of Appendix A)

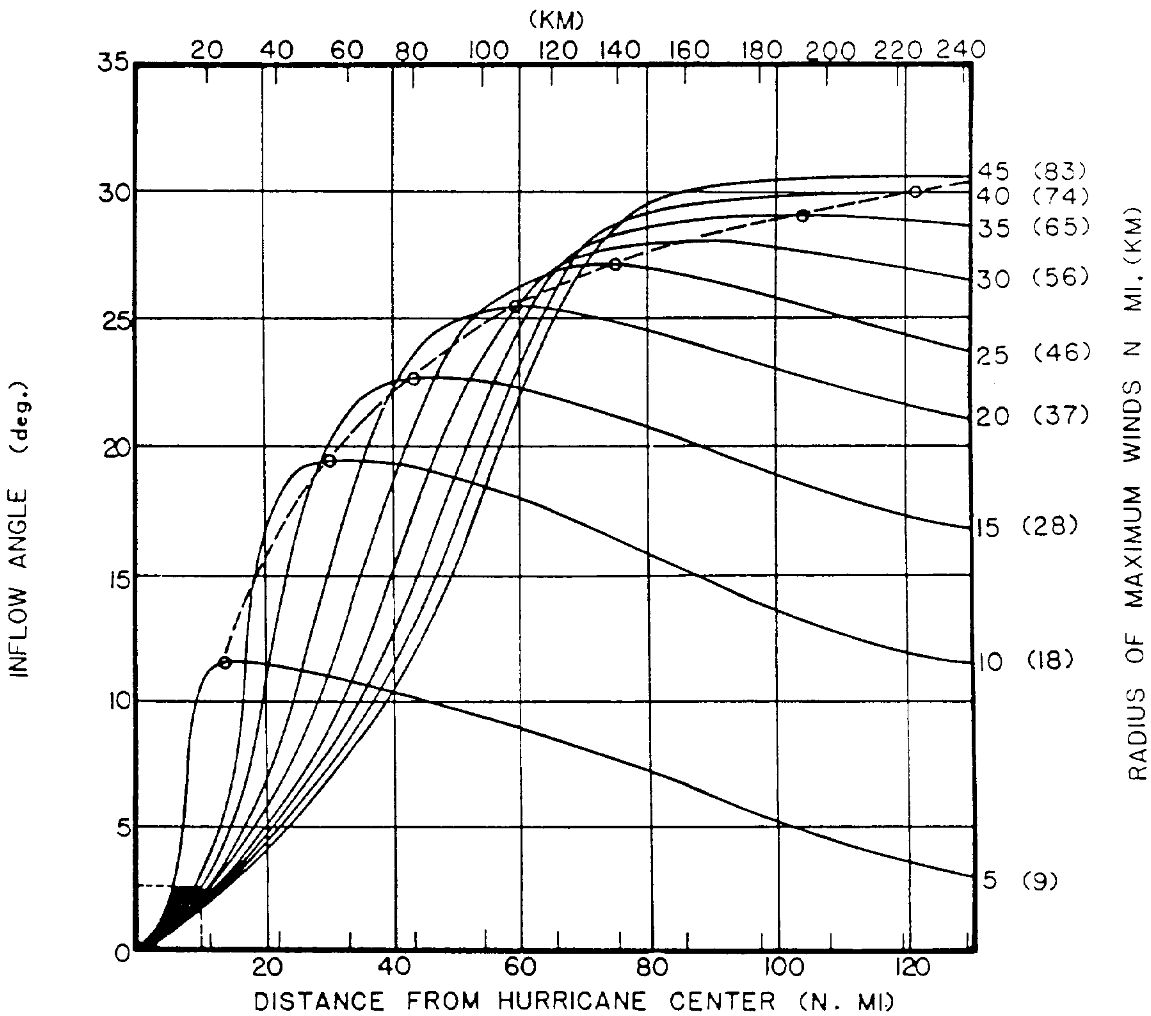

Figure C-13. Adopted SPH inflow angles versus distance from the hurricane center at selected R values. Open circles denote maximum inflow angle at each R. (item 57 of Appendix A)

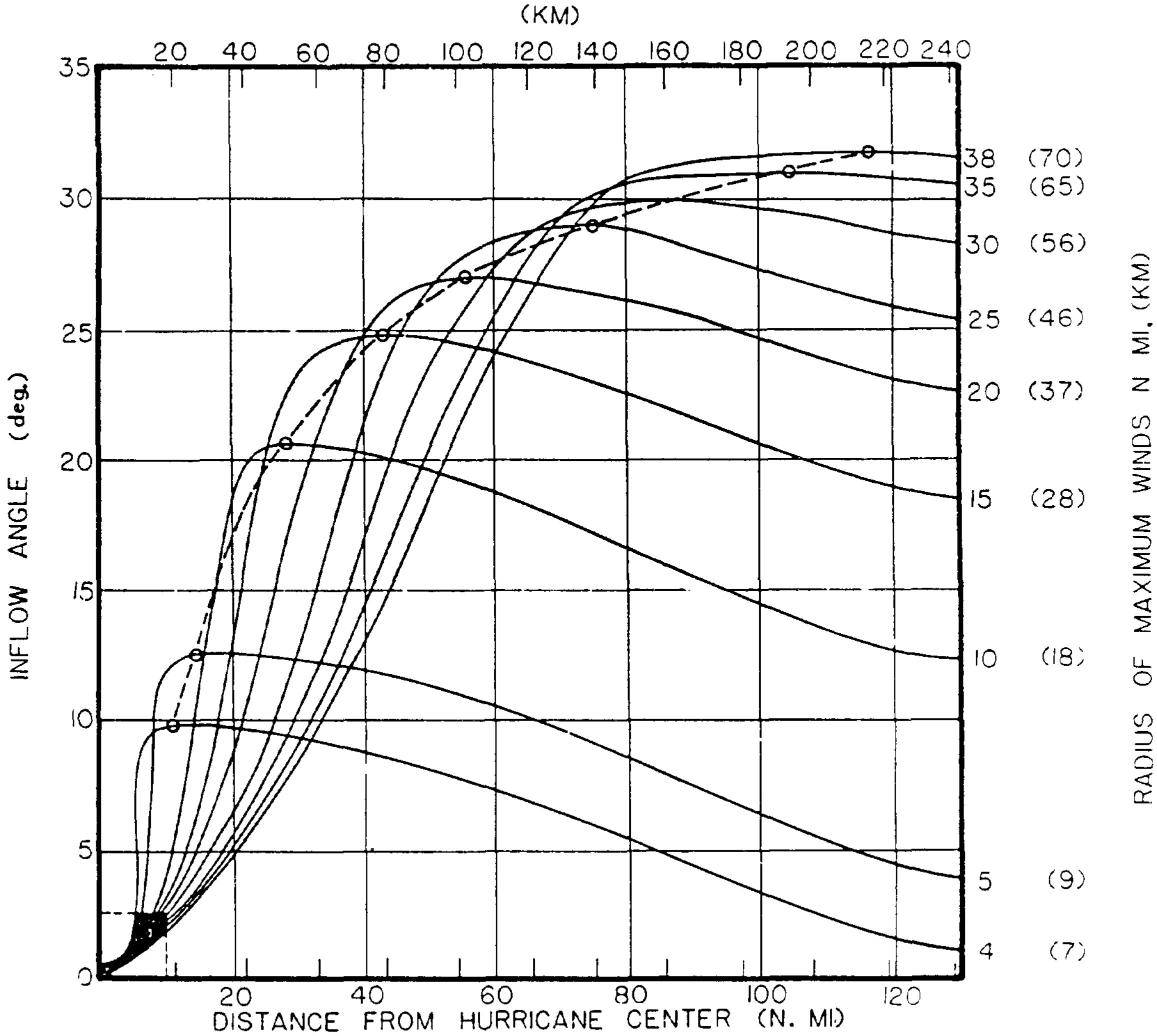

Figure C-14. Same as Figure C-13 except for the PMH. (item 57 of Appendix A)

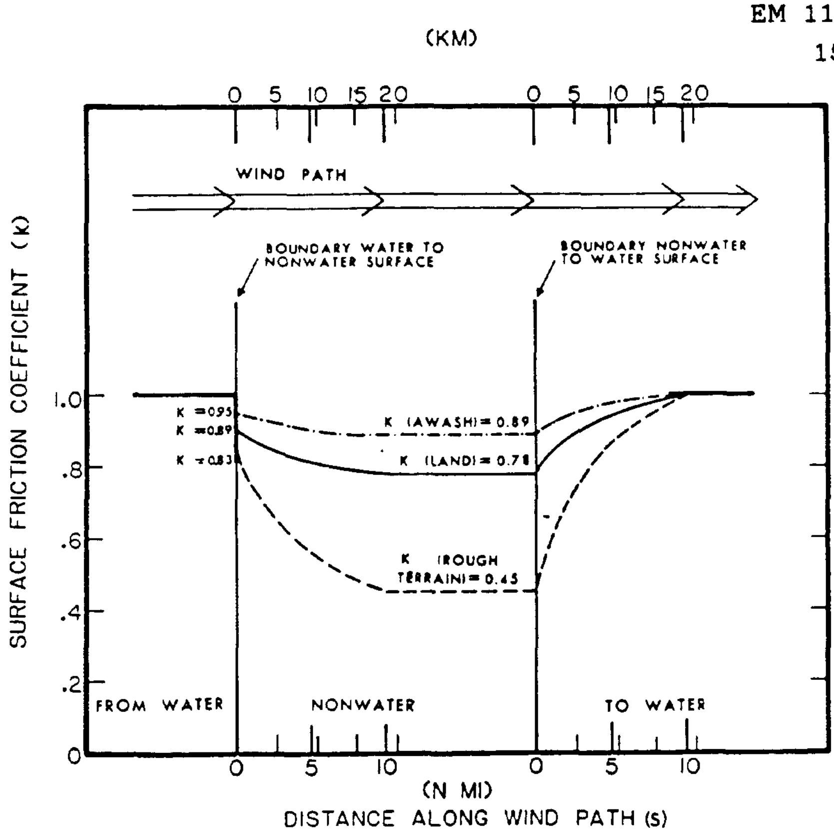

Figure C-15. Schematic of near shore frictional adjustments. (item 57 of Appendix A)

roughness categories which are designated as over water, awash, and rough terrain. According to technical Report NWS 23, awash is defined as normally dry ground with tree or shrub growth, hill dunes, which are noninundated; land--relatively flat noninundated terrain or buildings; rough terrain--major urban areas, dense forest, and mountains with abrupt changes in elevation over short distance. It is to be noted from Figure C-15 that the surface friction coefficient k varies only over a distance of 10 nautical miles when wind blows from water to nonwater areas or from nonwater areas to water areas.

g. Adjustment of Wind Speed for Filling Overland. When the hurricane center or eye crosses the coast and moves into inundated land areas the winds speed decrease due to filling. This weakening of the hurricane may be approximated by reducing the overwater SPH and PMH wind speed values by an adjustment factor. This factor has been derived for three separate geographic regions A, B, and C. The adjustment factor for these regions are shown in Figure C-16 and the geographic regions are shown in Figure C-17.

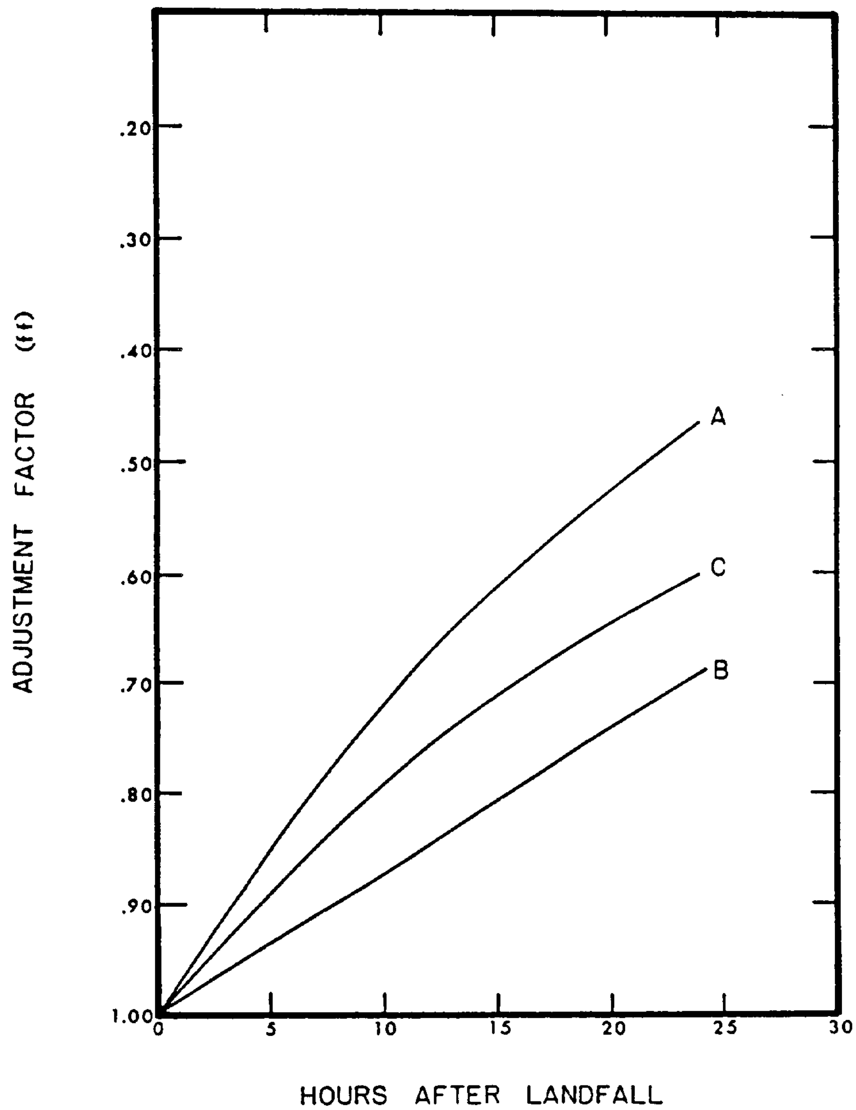

Figure C-16. Smoothed adjustment factor curves for reducing hurricane wind speeds when center is overland for three geographic regions defined in Figure C-17. (item 57 of Appendix A)

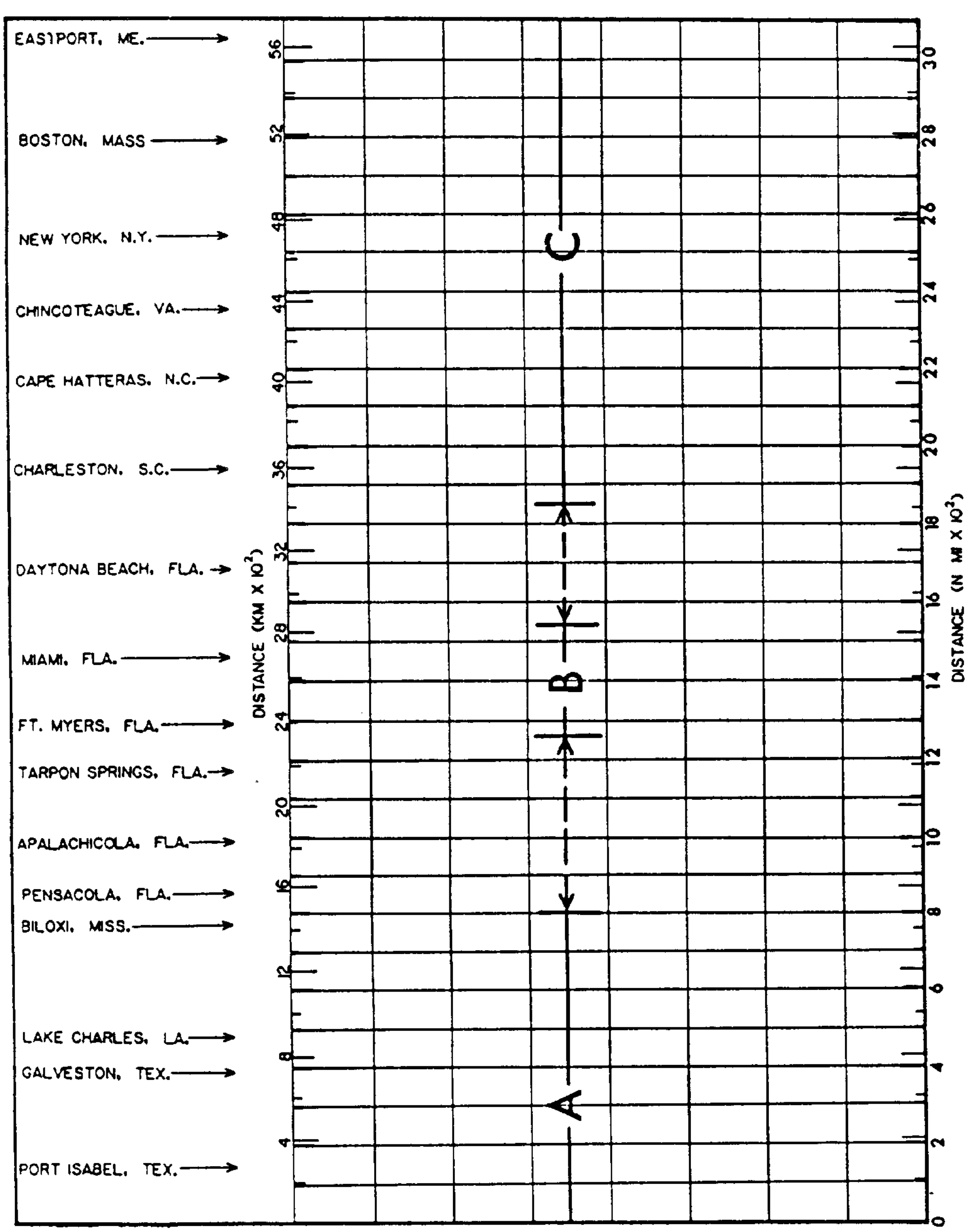

Figure C-17. Limits of three geographic regions (A, B, and C). Dashed lines delineate where linear interpolation should be used to develop intermediate curves in Figure C-16. (item 57 of Appendix A)

f. The Stalled PMH. A slow moving PMH is defined as being stalled when the forward speed $V_f < 5$ knots (9km/hr). Wind speeds decrease with time after stall provided that the forward speed is maintained in the stalled range. The percentage decrease in the winds for a PMH with time after stall is shown in Figure C-18. The curve provided in this figure is applicable along the gulf and east coasts south of Virginia-North Carolina border (milepost 2260).

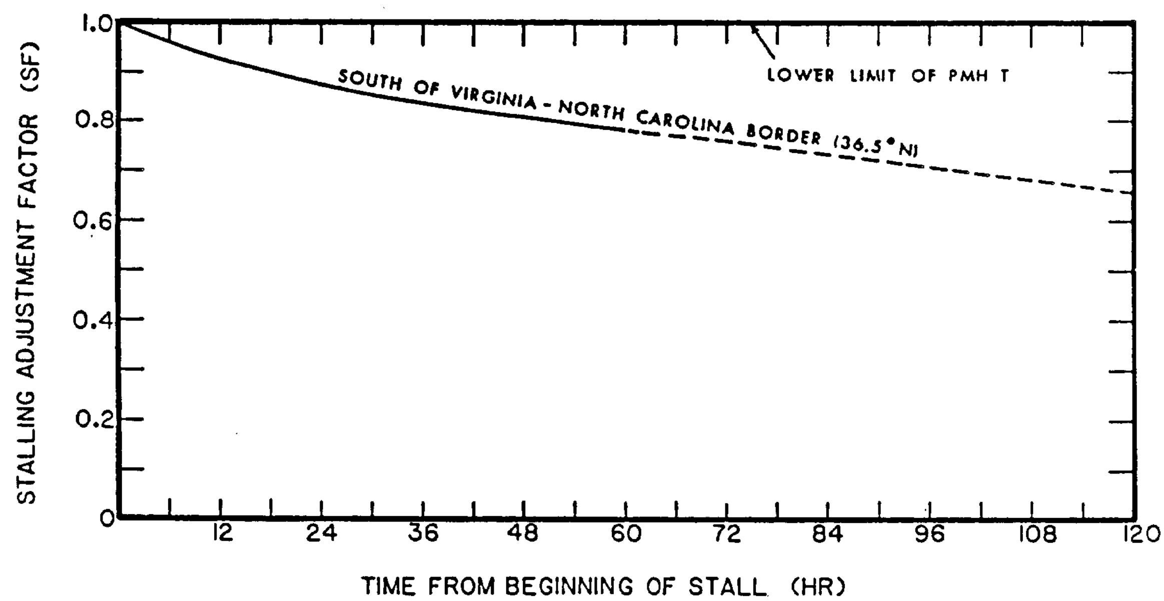

Figure C-18. Stalling adjustment factor curve for the PMH to be used south of the Virginia - North Carolina border (36.5° N). (item 57 of Appendix A)